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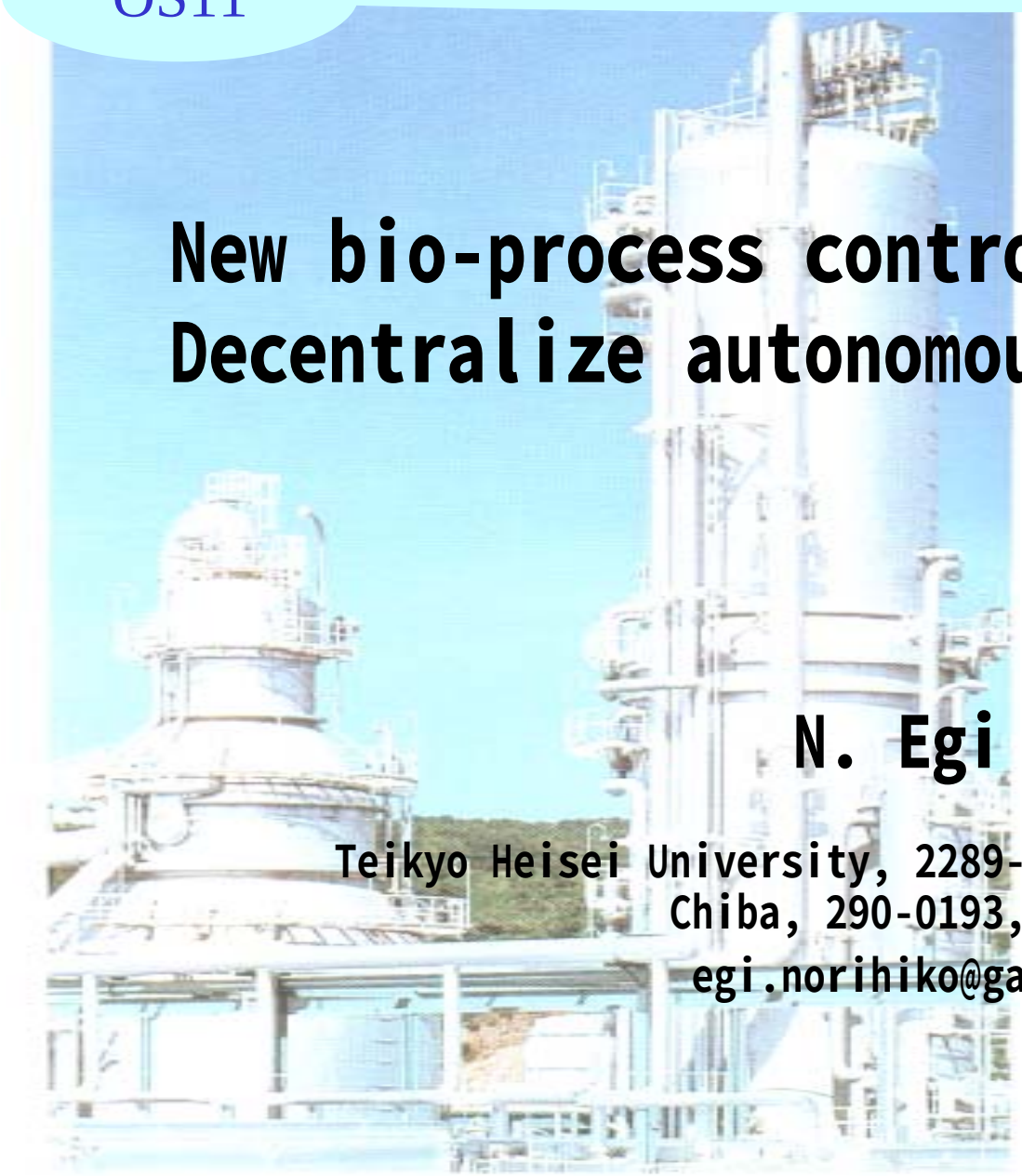

New bio-process control scheme: Decentralize autonomous control system

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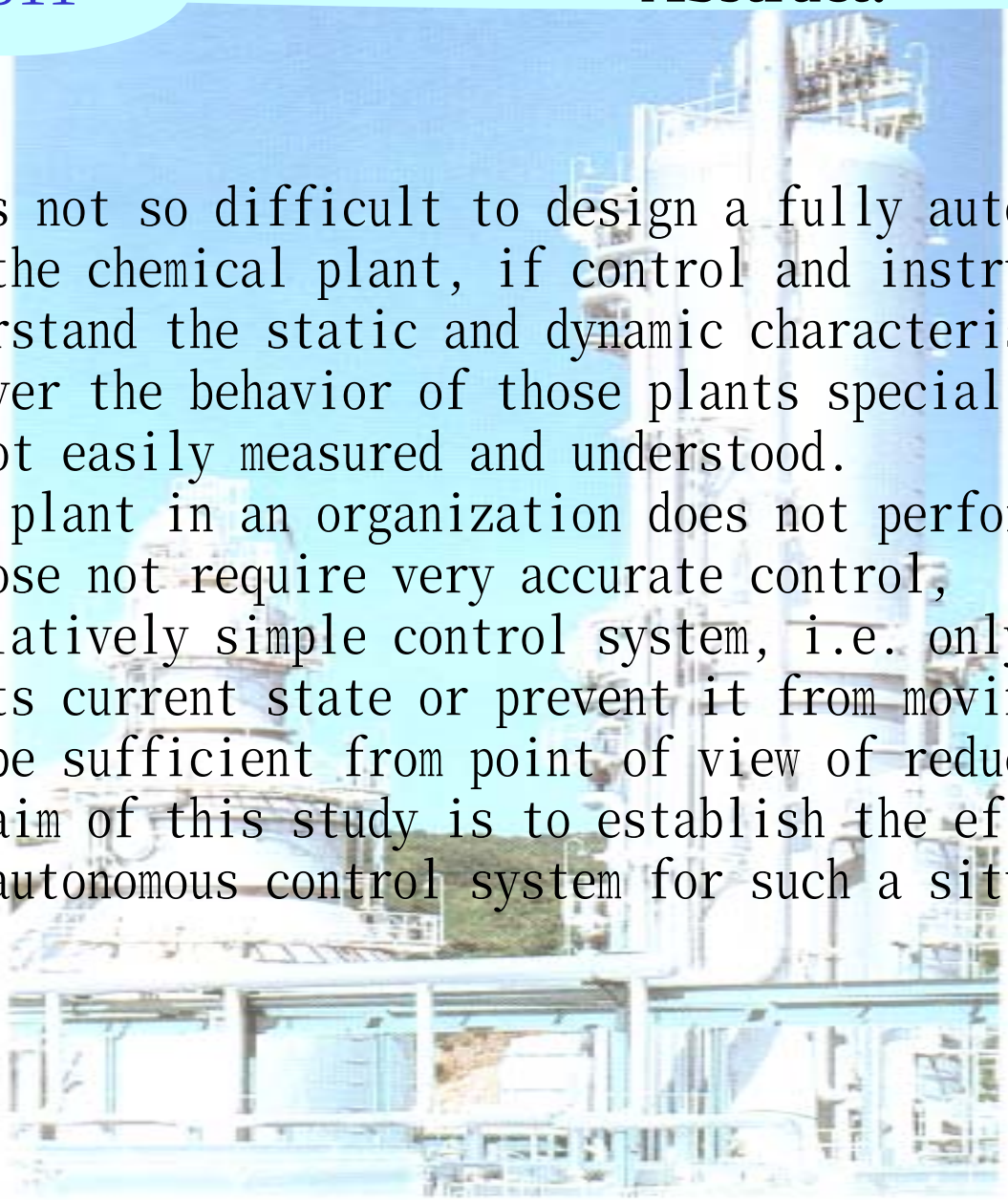
Abstract:

It is not so difficult to design a fully automatic control system for the chemical plant, if control and instrumentation engineers understand the static and dynamic characteristics of that plant. However the behavior of those plants specially so-called bio-plants is not easily measured and understood.
If a plant in an organization does not perform a vital role or dose not require very accurate control, a relatively simple control system, i.e. only to maintain the plant at its current state or prevent it from moving into abnormal states, may be sufficient from point of view of reducing the operators. The aim of this study is to establish the effectiveness of the autonomous control system for such a situation.



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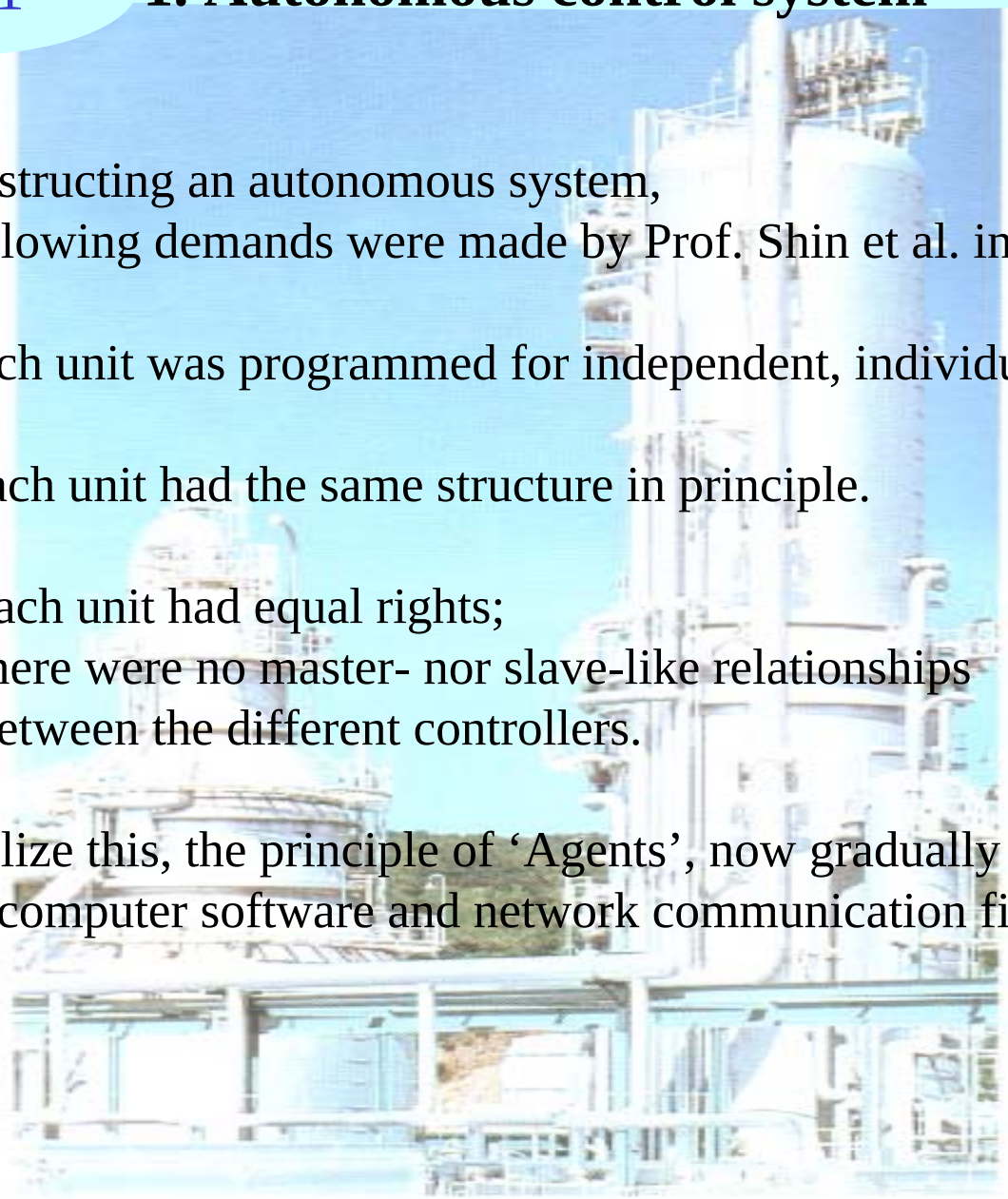
1. Autonomous control system



In constructing an autonomous system,
the following demands were made by Prof. Shin et al. in 1995.

(1) Each unit was programmed for independent, individually control section.

(2) Each unit had the same structure in principle.

(3) Each unit had equal rights;
there were no master- nor slave-like relationships
between the different controllers.

To realize this, the principle of ‘Agents’, now gradually becoming popular
in the computer software and network communication fields, was adopted.

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2. Image of autonomous control system

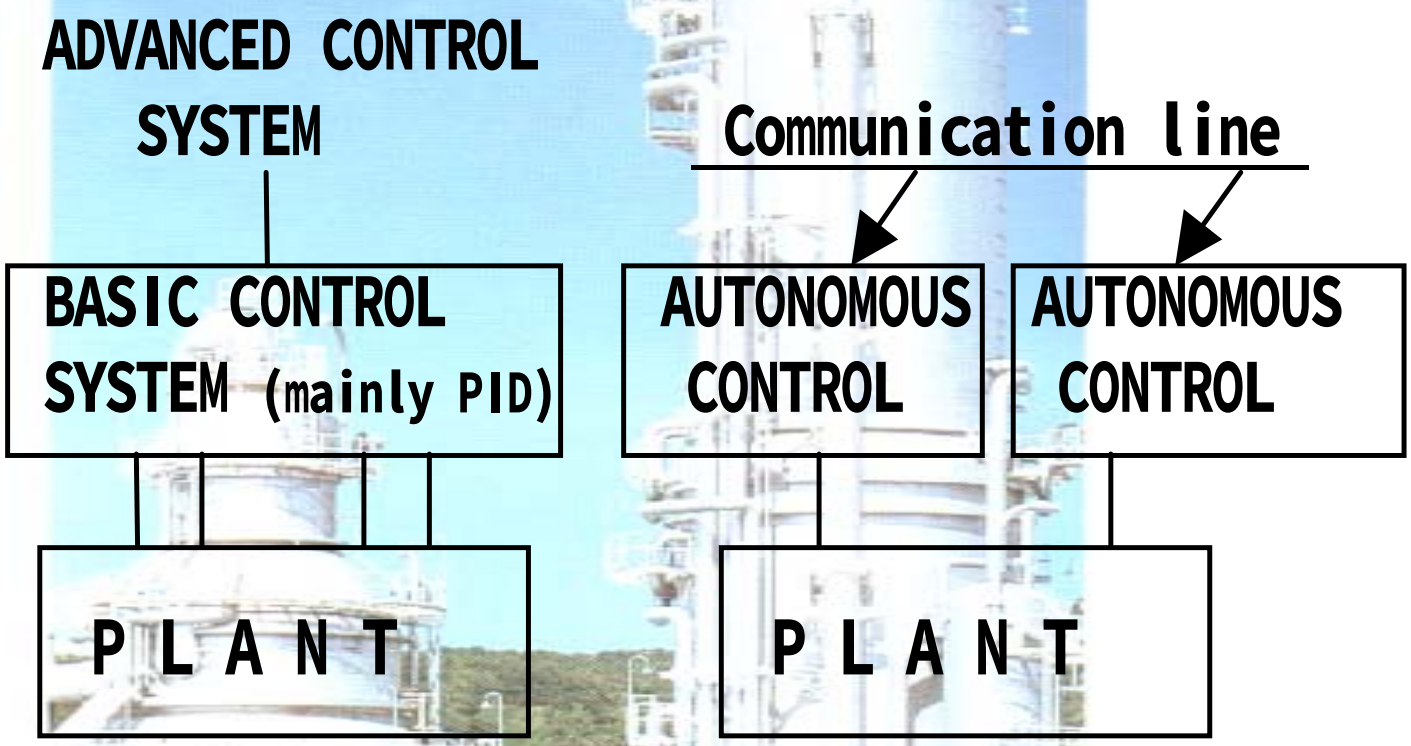

Fig. 1 Advanced vs. autonomous control

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3. Proposed autonomous control system

A ‘Happiness Index’ (HI) was introduced.
Each Agent should be ‘happy’ with its decision making, with a higher value of HI.
In the present work, a 2nd order function of the form Eq.(1) was used for HI,
as schematically illustrated in Fig.2.

$$HI = 1/A \times X \times (2 - X/A) \qquad (1)$$

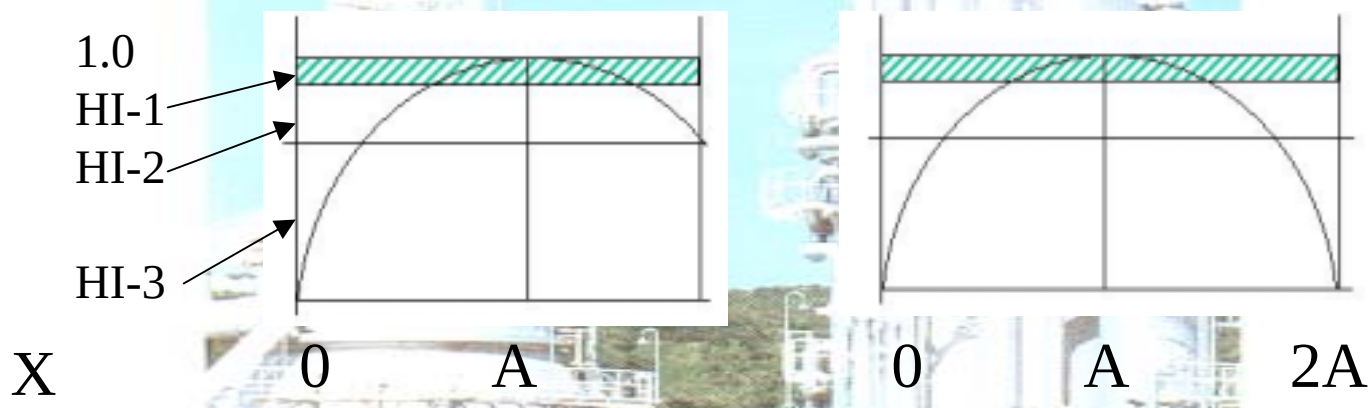

Fig. 2 Form of Happiness Index

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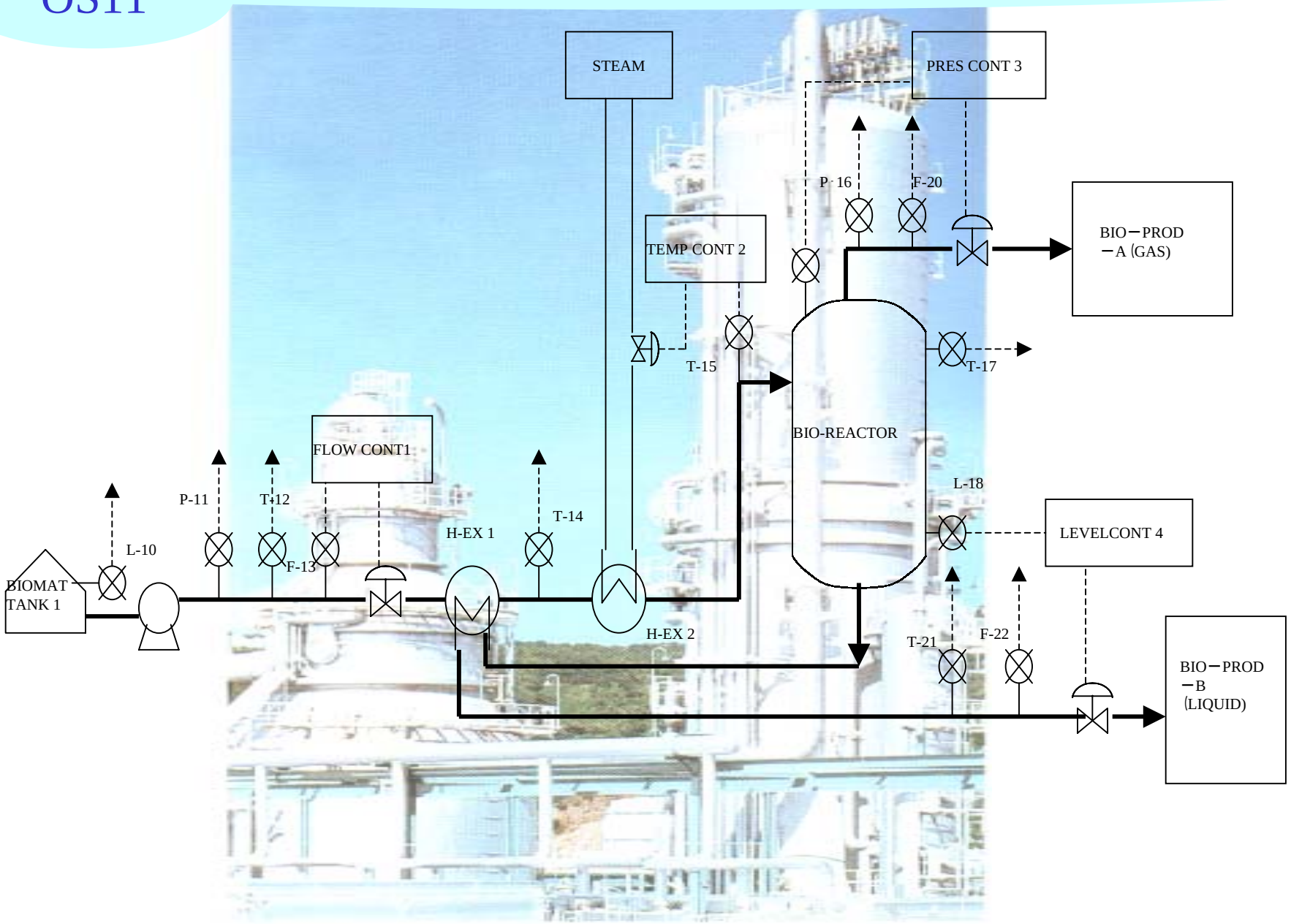
STEAM
PRES CONT 3
P-16
F-20
BIO－PROD
－A (GAS)
TEMP CONT 2
T-15
T-17
BIO-REACTOR
FLOW CONT1
P-11
T-12
T-14
L-18
LEVELCONT 4
H-EX 1
L-10
F-13
BIOMAT
TANK 1
H-EX 2
T-21
F-22
BIO－PROD
－B
(LIQUID)

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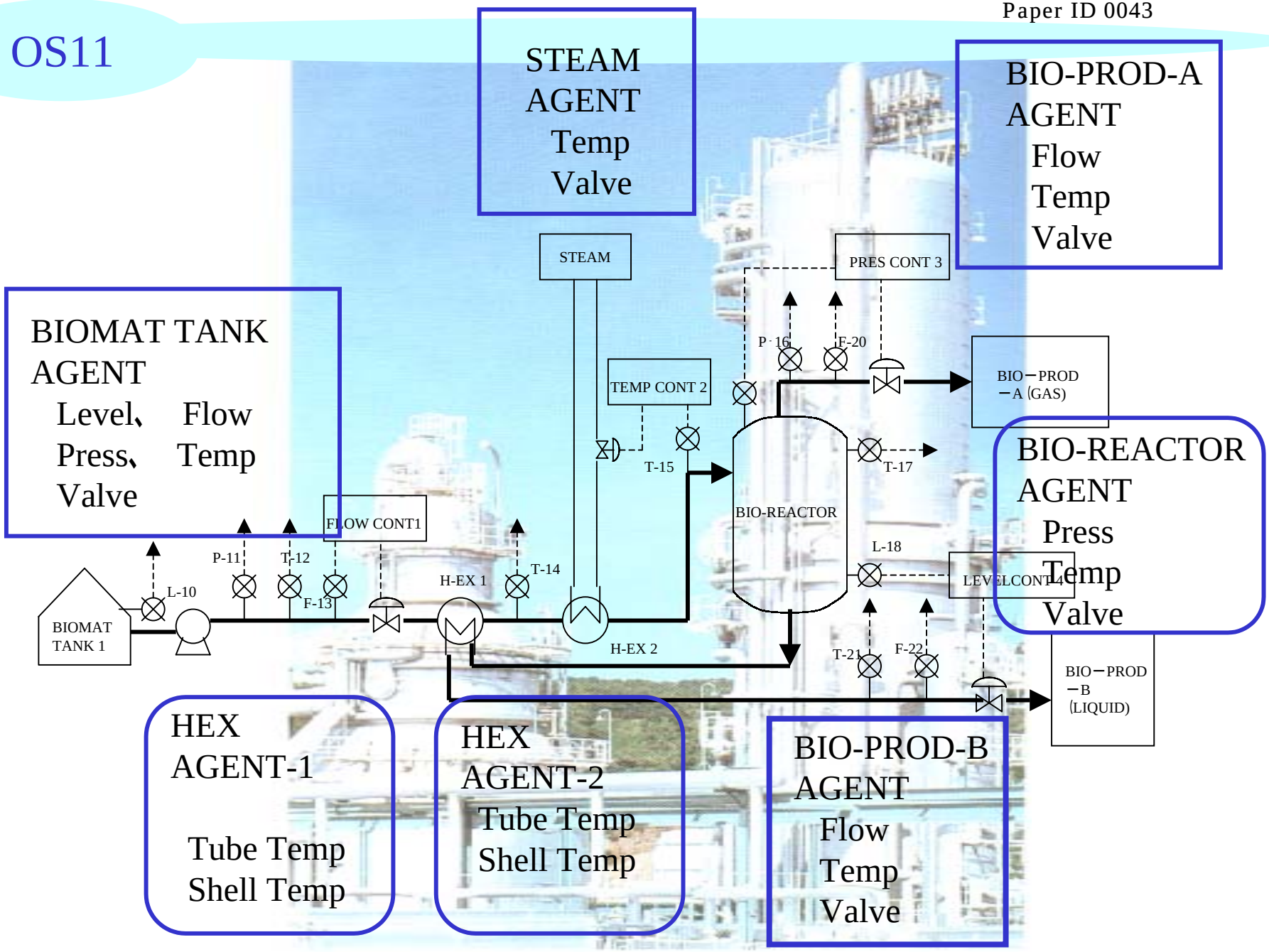
STEAM
AGENT
Temp
Valve
BIO-PROD-A
AGENT
Flow
Temp
Valve
BIOMAT TANK
AGENT
Level、 Flow
Press、 Temp
Valve
BIO-REACTOR
AGENT
Press
Temp
Valve
HEX
AGENT-1
Tube Temp
Shell Temp
HEX
AGENT-2
Tube Temp
Shell Temp
BIO-PROD-B
AGENT
Flow
Temp
Valve
STEAM
PRES CONT 3
P-16
F-20
BIO－PROD
－A (GAS)
TEMP CONT 2
T-15
T-17
BIO-REACTOR
FLOW CONT1
P-11
T-12
F-13
L-10
H-EX 1
T-14
H-EX 2
L-18
LEVELCONT4
T-21
F-22
BIO－PROD
－B
(LIQUID)
BIOMAT
TANK 1

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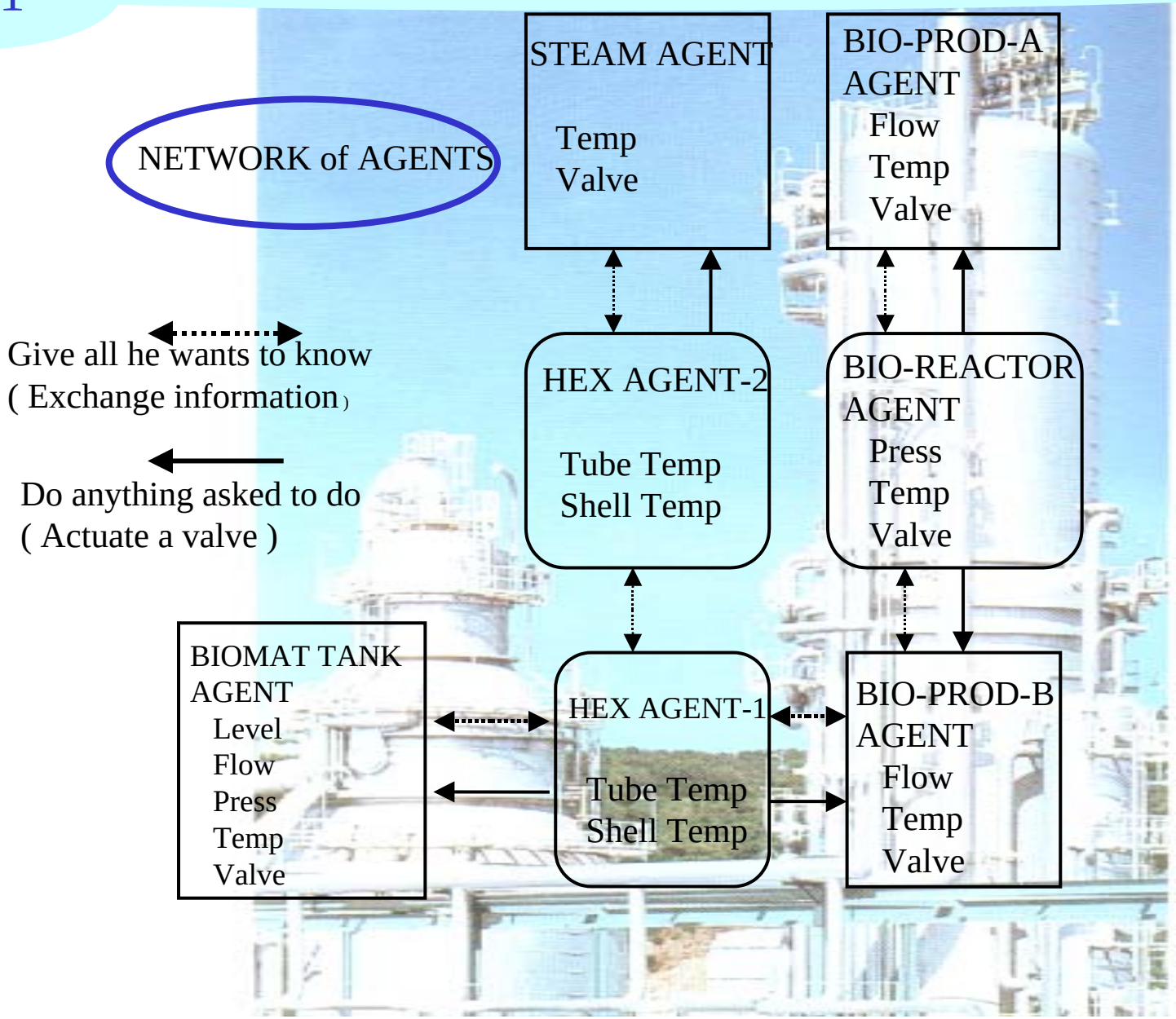
NETWORK of AGENTS
STEAM AGENT
Temp
Valve
BIO-PROD-A AGENT
Flow
Temp
Valve
Give all he wants to know
(Exchange information)
HEX AGENT-2
Tube Temp
Shell Temp
BIO-REACTOR AGENT
Press
Temp
Valve
Do anything asked to do
(Actuate a valve)
BIOMAT TANK AGENT
Level
Flow
Press
Temp
Valve
HEX AGENT-1
Tube Temp
Shell Temp
BIO-PROD-B AGENT
Flow
Temp
Valve

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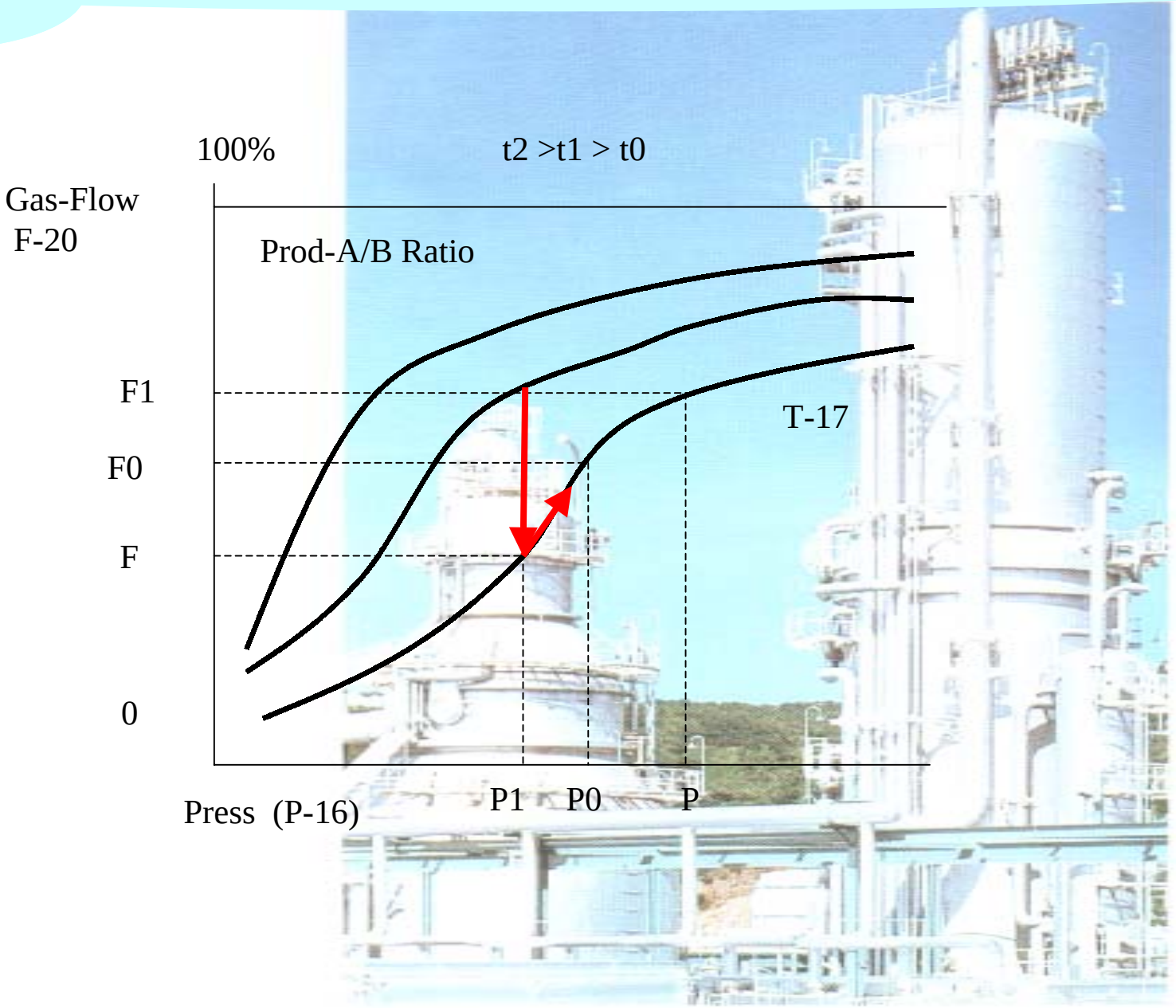
100%
t2 >t1 > t0
Gas-Flow
F-20
Prod-A/B Ratio
F1
F0
F
0
T-17
P1
P0
P
Press (P-16)

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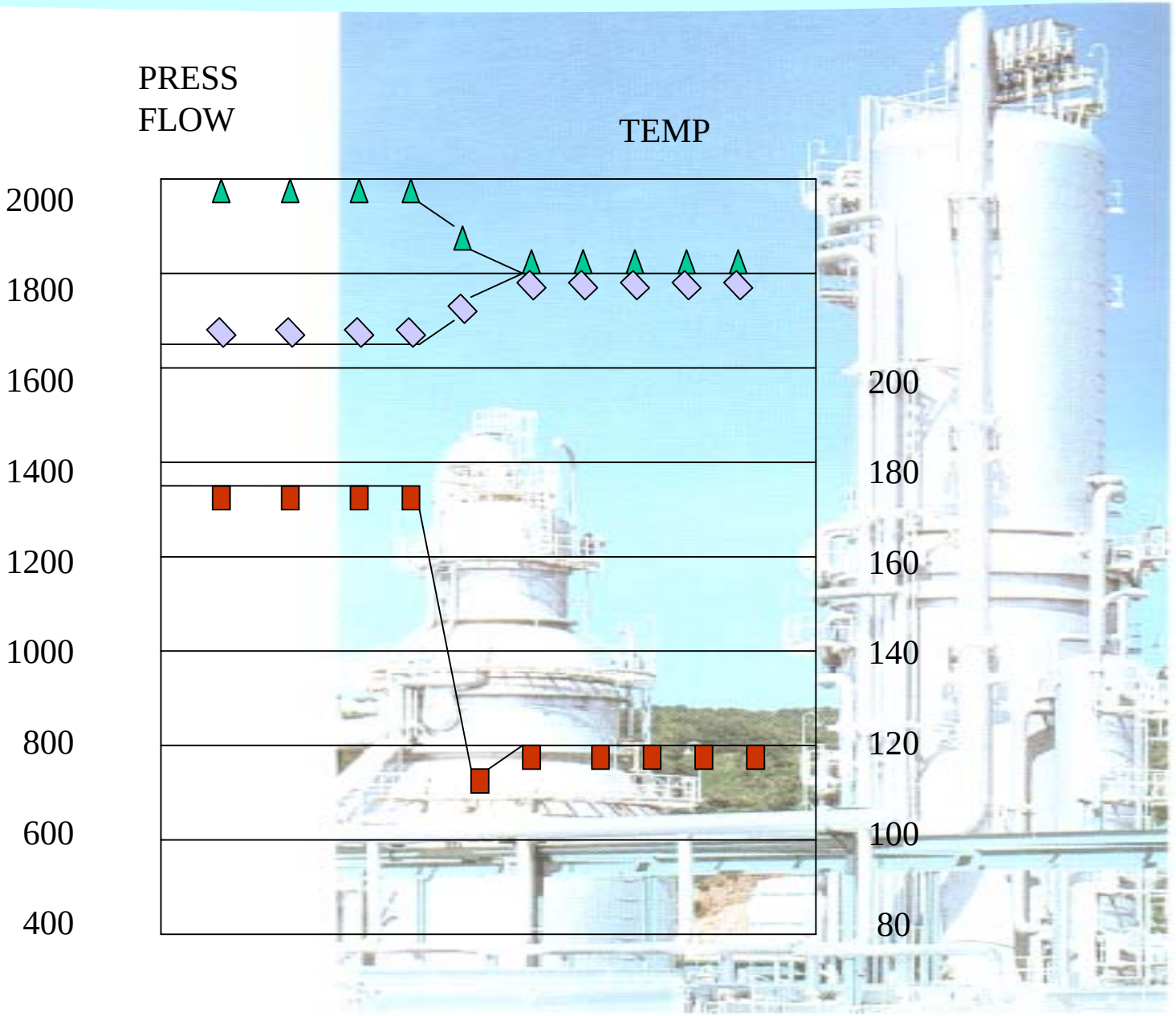
Result


PRESS
FLOW
TEMP
2000
1800
1600
1400
1200
1000
800
600
400
200
180
160
140
120
100
80

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Discussion

The results obtained were quite promising、 although a relatively simple bio-process simulator was employed for this preliminary study,

Several questions still remain open.

- Is there any possibility of upset of the control system?
- Is it possible to stop the overrunning of the control?
- Apparently, if the system were not given an appropriate objective function or HI, the control system would be likely to fail.
- In addition to HI, an Agent could have further knowledge about the system, i.e. a value above the maximum limit is not good, or under some conditions no action by the Agent itself is required except for asking help from one or more of the other Agents, which would prevent the system from being upset.
- To what extent is this system stable?
- How fast will it settle?

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These questions are not easy to answer, and the answer depends on the knowledge of each Agent.

If the Agent fail to cooperate with each other, what would the final outcome be?

Clearly, the result could be a mess. All Agents would continue to fluctuate around certain values. Arriving at such an unstable situation could be prevented by special command actions by the responsible Agents.

Could the system benefit from the introduction of a supervisory or patrolling Agent?

According to the initial definition, all Agents should be independent with equal rights. In this sense, a supervisory Agent would not be allowed.
But if a supervisory Agent is constructed to give others overall or summarized information about the whole plant, this would still fall within the definition.
In such a case, a supervisory or patrolling Agent would be useful for rapid settling in case of unexpectedly large upset.

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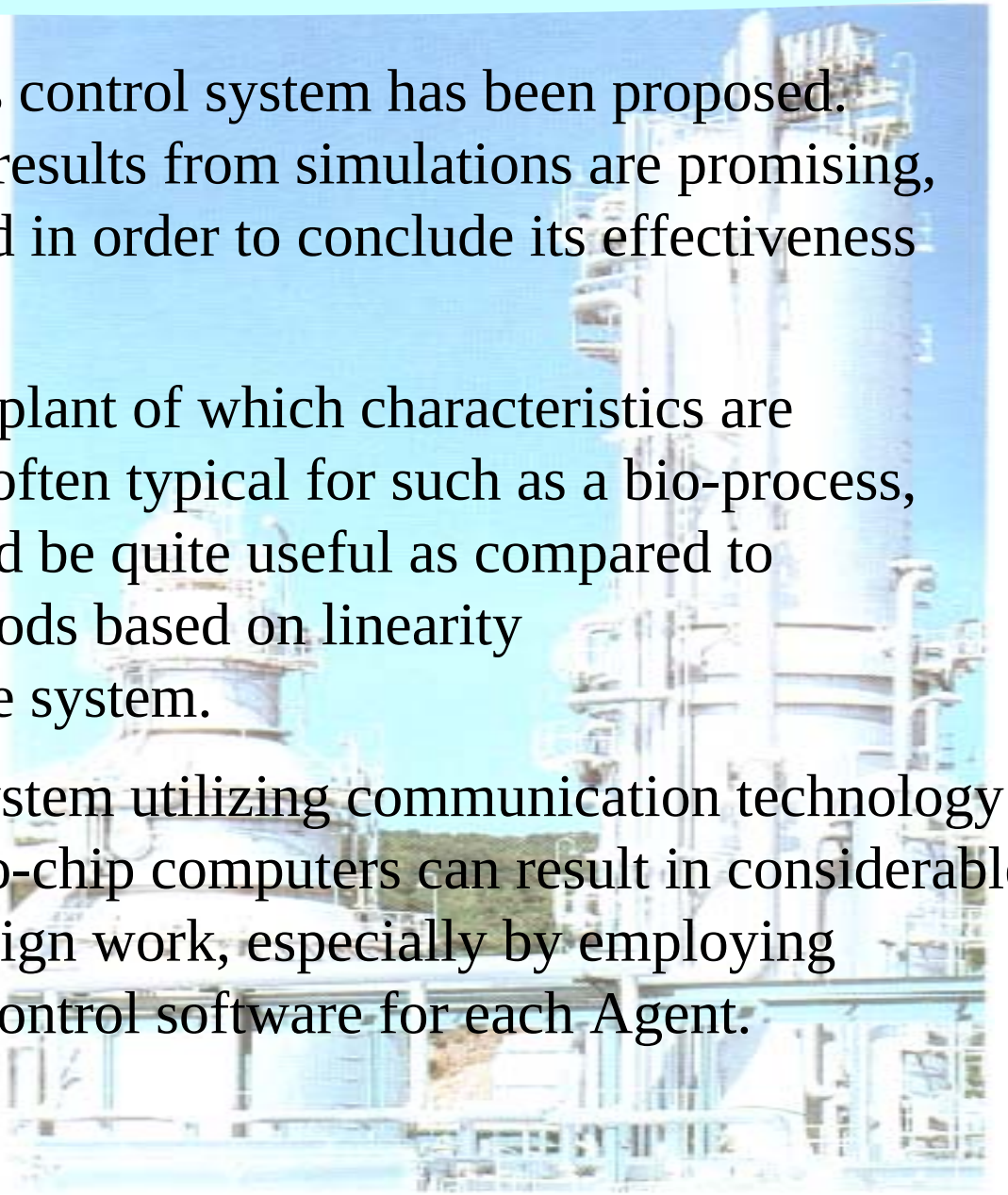
Conclusions



A concept for autonomous control system has been proposed. Although the preliminary results from simulations are promising, much more work is needed in order to conclude its effectiveness in real-life situations.

However, especially for a plant of which characteristics are only roughly known as is often typical for such as a bio-process, the concept proposed could be quite useful as compared to conventional control methods based on linearity and the transparency of the system.

Further, a decentralized system utilizing communication technology and the capability of micro-chip computers can result in considerable savings in engineering design work, especially by employing the same structure of the control software for each Agent.

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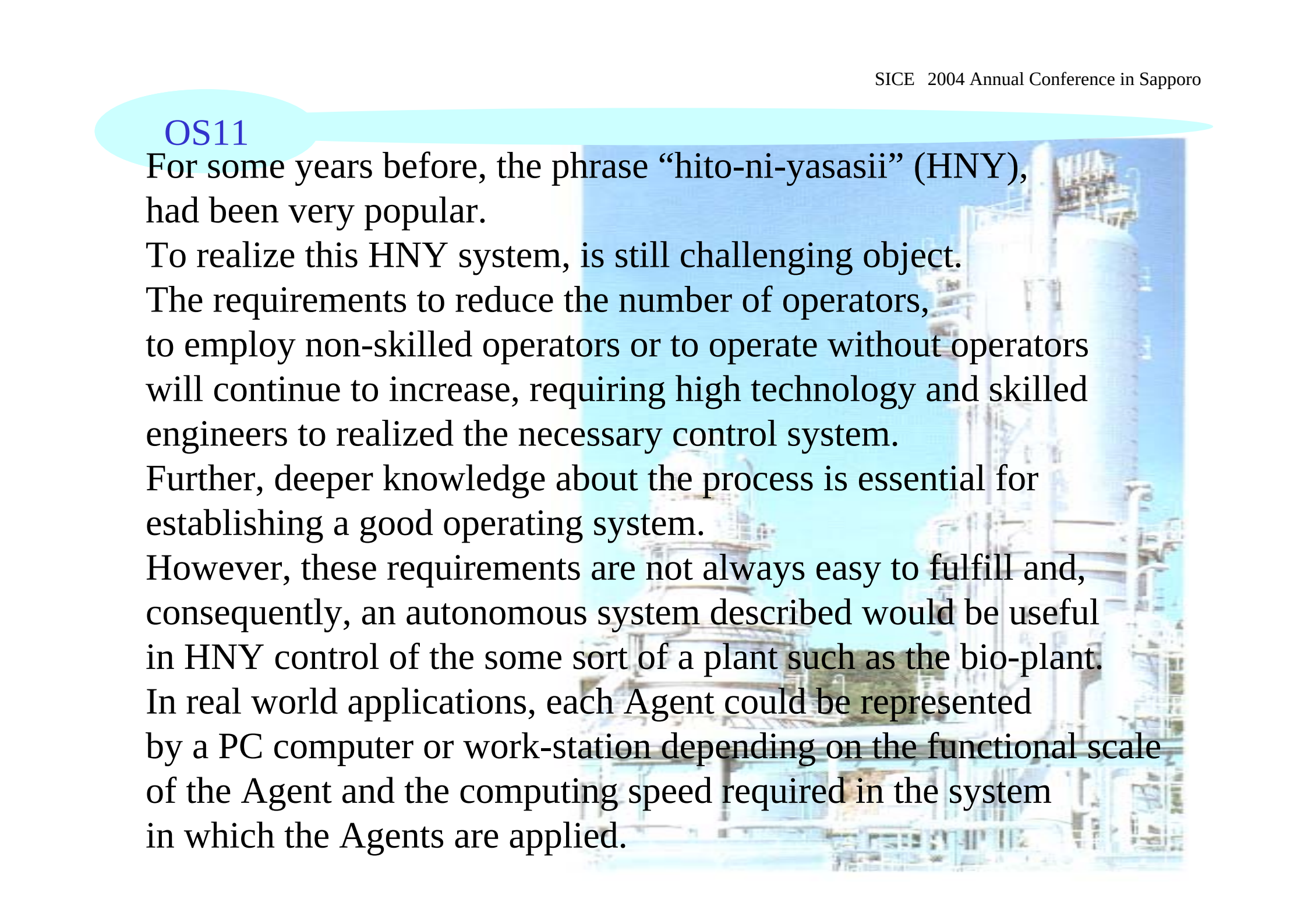

For some years before, the phrase “hito-ni-yasasii” (HNY), had been very popular.
To realize this HNY system, is still challenging object.
The requirements to reduce the number of operators, to employ non-skilled operators or to operate without operators will continue to increase, requiring high technology and skilled engineers to realized the necessary control system.
Further, deeper knowledge about the process is essential for establishing a good operating system.
However, these requirements are not always easy to fulfill and, consequently, an autonomous system described would be useful in HNY control of the some sort of a plant such as the bio-plant.
In real world applications, each Agent could be represented by a PC computer or work-station depending on the functional scale of the Agent and the computing speed required in the system in which the Agents are applied.

Acknowledgement

Thank you for your attention.

I would like to thank Dr. Takeru Irab, IT Engineering Ltd.,
for giving me a hint of the autonomous control method,
for his efforts to construct the process simulator and the Agent system
running on a personal computer, and for the execution of the many simulations.

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